Chapter 9

ADDITIONAL ENVIRONMENTAL IMPROVEMENT OPPORTUNITIES

This chapter presents module descriptions for identifying additional environmental improvement opportunities, including the following modules:

- Pollution Prevention Opportunities Assessment.
- Control Technologies Assessment.

Pollution prevention involves changes in production, operating processes, or raw materials used to prevent or reduce pollution at the source. Although the entire CTSA process can be thought of as a means of evaluating pollution prevention opportunities, the Pollution Prevention Opportunities Assessment module involves assessing workplace practices and process conditions for pollution prevention opportunities above and beyond the use of a substitute. This assessment results in a specific list of suggested actions that could be taken to reduce or eliminate pollution for each of the alternatives.

The Control Technologies Assessment module involves an assessment of end-of-the-pipe treatment and disposal technologies for pollution generated for the alternatives. Control technologies are used to reduce the toxicity and/or volume of pollutants released. The information from this module can be used to identify available options that may be used for the evaluated process and substitutes.

Data from the Pollution Prevention Opportunities Assessment module do not necessarily flow into other modules in a CTSA. This module is intended to give individual businesses ideas for preventing pollution, regardless of which alternative they use. Recommended control technologies from the Control Technologies Assessment module may flow into the Cost Analysis module for costing, particularly if the controls are required by environmental regulation.

POLLUTION PREVENTION OPPORTUNITIES ASSESSMENT

OVERVIEW: Pollution prevention is the process of reducing or preventing pollution at the source through changes in production, operation, and materials use. Pollution prevention can result in reduced materials usage, pollution control, and liability costs. It can also help protect the environment and may reduce risks to worker health and safety.

The improved Pollution Prevention Opportunities Assessment module focusses on workplace practices and equipment (other than the substitutes being evaluated in a CTSA) that can be used to reduce pollution at the source. It also describes methods individual businesses can use to identify pollution prevention opportunities, which often apply to many or all of the substitutes being evaluated.

GOALS:

- Perform a pollution prevention opportunities assessment for the specific process under consideration.
- Arrive at a specific list of actions which can be implemented to prevent pollution.

PEOPLE SKILLS: The following lists the types of skills or knowledge that are needed to complete this module.

- Knowledge of the process under review, including the types and amounts of chemicals used in the process; the sources, nature and quantity of waste streams; and process optimization techniques.
- Knowledge of waste tracking for the process under review, including access to records of rates of materials purchases and associated costs.
- Knowledge of federal, state, and local waste stream release reporting and historical waste disposal practices.

Within a business or DfE project team, the people who might supply these skills include a plant engineer, environmental engineer, line supervisor, line operator, or suppliers of chemicals or equipment.

DEFINITION OF TERMS:

<u>Pollution Prevention</u>: As defined in the Pollution Prevention Act of 1990, pollution prevention is the reduction in the amount or hazards of pollution at the source (see Source Reduction).

Recycling: In-process recovery of process material effluent, either on-site or off-site, which would otherwise become a solid waste, air emission, or a waste water stream.

Reuse: On-site recovery and subsequent introduction of a waste stream back into the process.

Source Reduction: As defined in the Pollution Prevention Act of 1990, any practice which: (1) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and (2) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants. Source reduction includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

Waste Management Hierarchy: National policy declared in the Pollution Prevention Act of 1990 which gives the following hierarchy to waste management, ordered from highest to lowest level of desirability:

- Pollution prevention at the source.
- Recycling in an environmentally safe manner.
- Treatment in an environmentally safe manner.
- Disposal or other release into the environment only as a last resort and in an environmentally safe manner.

APPROACH/METHODOLOGY: The following presents a summary of the technical approach or methodology for conducting a pollution prevention opportunities assessment. Steps 6 and 7 of the methodology concern implementing pollution prevention opportunities which would normally be done by individual businesses outside of the CTSA process. These steps are presented here to emphasize the importance of following through on a pollution prevention program.

Since the overall CTSA mainly focuses on pollution prevention through process modifications, reformulation or redesign of products, and chemical substitution, the methodology presented here focuses on identifying equipment modifications and improved workplace practices to prevent pollution. Further methodology details for Steps 3 and 4 follow this section.

Step 1: Obtain the process flow diagram from the Chemistry of Use & Process Description Module. The process flow diagram from this module provides the framework to identify process input and output streams, including waste point sources.

Step 2: Review the Workplace Practices & Source Release Assessment module to identify the types and quantities of hazardous and non-hazardous releases to air, land, or water, and the workplace practices associated with these releases.

Step 3: Evaluate each of the sources of releases and the associated workplace practices identified in Step 2 for pollution prevention opportunities. The best results occur when all plant personnel are involved in discussions to identify pollution prevention opportunities. In addition, EPA and many state agencies have prepared industry-specific guides to pollution prevention. Many states also provide pollution prevention technical assistance to small- and medium-sized businesses.

Step 4: Evaluate each of the pollution prevention opportunities identified in Step 3 to set priorities for implementing a pollution prevention activity. Factors that could be considered include:

- Company priorities (e.g., for the elimination of a "problem" chemical such as an EPA-regulated solvent).
- Relative amounts of waste streams.
- Relative toxicity of waste streams.
- Percentage of an existing waste stream that would be prevented.
- Regulatory status of waste streams, both before and after a pollution prevention opportunity is implemented.
- Employee health (e.g., cancer risk) and safety (e.g., fire risk).
- Cost of waste steam management (e.g., treatment and disposal costs).
- Ease of implementation.
- Cost of implementation and payback period.
- Potential for waste stream recyclability or reuse.
- Potential for regulations that may phase out certain chemicals or processes.

Step 5: Prior to implementing pollution prevention opportunities, review federal, state, and local regulations relating to the waste stream(s) under consideration. The Regulatory Status module should have relevant information pertaining to existing wastes streams, but may not cover new waste streams or changes in waste stream characteristics that would result from implementing a pollution prevention measure. This step is needed to assure that pollution prevention measures do not result in a violation of existing regulations. For example, if a pollution prevention measure would result in a waste water discharge of a regulated substance beyond acceptable limits, the measure would have to be eliminated from further consideration. Measures that shift pollution from one media to another or create new waste streams are not typically considered to be pollution prevention, however.

Step 6: Develop a schedule for implementing technically and economically feasible pollution prevention opportunities. (Pollution prevention projects are usually more cost-effective than indicated by traditional costing methods that lump environmental compliance costs into an overhead cost factor and do not consider potential liability costs and less tangible benefits. See the Cost Analysis module for more details.)

Step 7: Conduct periodic, in-house audits to assess the effectiveness of the pollution prevention program and to identify new pollution prevention opportunities on a regular basis.

METHODOLOGY DETAILS: This section presents the methodology details for completing Steps 3 and 4. If necessary, additional information on conducting a pollution prevention opportunities assessment can be found in the published guidance.

Details: Step 3, Identifying Pollution Prevention Opportunities

Pollution Prevention through Improved Workplace Practices

Improved workplace practices that prevent pollution are often inexpensive and easy to implement, while offering almost immediate reduction of waste. The basic framework for pollution prevention through improved workplace practices involves:

- Raising employee awareness of pollution prevention benefits.
- Materials management and inventory control.
- Process improvement.
- Periodic in-house audits.

Raising employee awareness is the best way to get employees to actively participate in a pollution prevention program. Materials management and inventory control includes understanding how chemicals and materials flow through a facility to identify the best opportunities for pollution prevention. Process improvement through improved workplace practices includes reevaluating the day-to-day operations in a facility to identify good operator practices that prevent pollution. Finally, in-house audits are used to collect real-time data on the effectiveness of a pollution prevention program. This step gives both operators and managers the incentive to strive for continuous improvement.

Examples of process improvements through improved workplace practices include:

- Training operators in techniques to optimize the process (e.g., manual adjustment of pH levels to extend the life of a plating bath).
- Training of employees to not "overuse" materials (e.g., only using the amount needed to perform a particular task).
- Covering containers to reduce evaporative losses (e.g., covering solvent containers while not in use).
- Covering containers of chemicals between process steps to minimize contamination.
- Improved inventory control (e.g., using chemicals before the listed expiration date).
- Improved handling of materials (e.g., training of personnel to reduce spills and wastage of liquids and solids).
- Segregation of raw materials and waste streams.

Pollution Prevention through Equipment Modifications

Modifying equipment to prevent pollution is usually more complicated and costly than changes in workplace practices. However, substantial improvements in process operation can be achieved through equipment modifications that are not equipment, process or technology substitutions. For example, pollution prevention through equipment modification for a chemical reactor/chemical delivery system could include:

- Increasing reactor volume and monitoring residence time to obtain an increased product yield.
- Installing sample loops on product sampling purge line to return unused sample to the process.
- Using an adjustable applicator system to control the quantity and direction of a chemical product (e.g., cleaning agent, paint or coating, etc.) applied to a substrate.
- Installing a recirculation system to recirculate chemicals that are being discarded before they are completely spent.

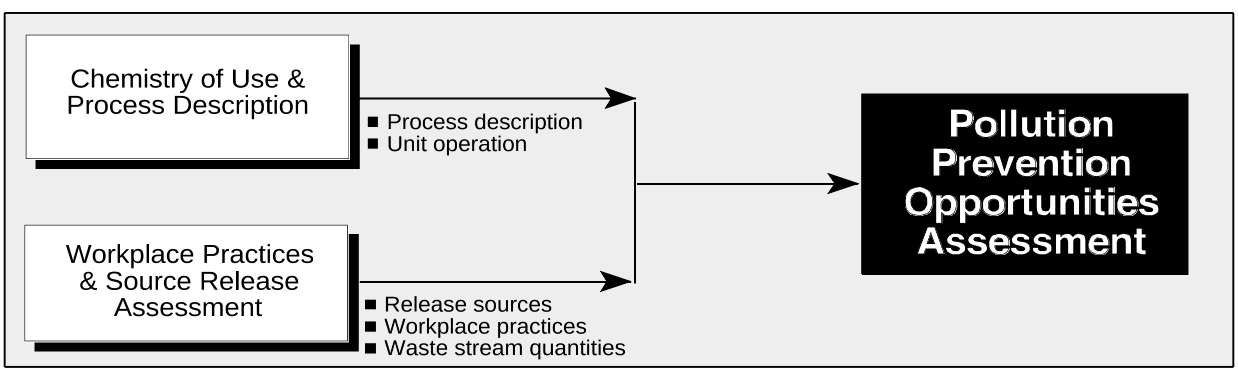
Details: Step 4, Setting Priorities

The percentage of a waste stream that would be prevented by a pollution prevention activity can be estimated based on:

- Knowledge of chemical reactions and mass and energy balance calculations.
- Professional judgement and process experience of the process specialist, waste manager, process operator and others familiar with the process.
- Data provided by vendors (e.g., chemical vendors).
- Data from published case studies of similar waste streams or facilities (see reference section).

FLOW OF INFORMATION: This module can be used alone to help identify pollution prevention opportunities in a commercial business or manufacturing facility. In a CTSA, this module receives data from the Chemistry of Use & Process Description and Workplace Practices & Source Release Assessment modules. Example information flows are shown in Figure 9-1.

FIGURE 9-1: POLLUTION PREVENTION OPPORTUNITIES ASSESSMENT MODULE: EXAMPLE INFORMATION FLOWS



ANALYTICAL MODELS: None cited.

PUBLISHED GUIDANCE: Table 9-1 presents examples of published guidance on performing a pollution prevention opportunities assessment. Additional guidance can be obtained by contacting the U.S. Environmental Protection Agency's Pollution Prevention Information Clearinghouse at (202) 260-1023.

TABLE 9-1: PUBLISHED GUIDANCE ON PERFORMING POLLUTION PREVENTION OPPORTUNITIES ASSESSMENT

Reference	Type of Guidance
Brown, Lisa, Ed. 1992. *Facility Pollution Prevention Guide.*	Methods for performing assessments, ranking of pollution prevention options, and assessment of waste reduction benefits.
Freeman, Harry M. 1994. *Industrial Pollution Prevention Handbook.*	Technical reference on pollution prevention strategies and technologies.
Higgins, Thomas E. 1989. *Hazardous Waste Minimization Handbook.*	Outlines specific approaches to industrial pollution prevention.
Metcalf, Cam, Ed. 1991. *Waste Reduction Assessment and Technology Transfer Training Manual.*	Example of pollution prevention assistance provided by many states. Check with local state agencies for a state specific guide.
Theodore, Lewis and Young C. McGuinn. 1992. *Pollution Prevention*.	Outlines assessment procedures.
U.S. Environmental Protection Agency. 1992h. *Pollution Prevention Information Exchange System: User Guide Version 2.1*	Users guide on accessing online database and performing information searches.
U.S. Environmental Protection Agency. 1992i. *Pollution Prevention Case Studies Compendium.*	Case studies of pollution prevention assessments.
U.S. Environmental Protection Agency. 1992j. *Guide to Pollution Prevention: The Metal Finishing Industry*.	Provides pollution prevention guidelines for specific industries. Call EPA at (513) 569-7562 to obtain guides for other industries or processes.
U.S. Environmental Protection Agency. 1992k. *PIES. Pollution Prevention Information Exchange System*.	On-line data base containing a compilation of different types of pollution prevention data.
U.S. Environmental Protection Agency. 1994m. *Pollution Prevention Directory*.	Directory of U.S. pollution prevention sources.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

DATA SOURCES: None cited.

CONTROL TECHNOLOGIES ASSESSMENT

OVERVIEW: Control technologies can be used to minimize the toxicity and volume of released pollutants. Most control technologies involve altering either the physical or chemical characteristics of a waste stream to isolate, alter the concentration of, or destroy target chemicals. This module describes methods for identifying control technologies that may be suitable for on-site treatment and disposal of product or process waste streams.

GOALS:

- Identify treatment and disposal options for residual waste(s) remaining after the implementation of pollution prevention or waste minimization (including recycling) opportunities.

PEOPLE SKILLS: The following lists the types of skills or knowledge that are needed to complete this module.

- Knowledge of materials, chemical properties, and available processes to ameliorate hazardous properties, including ability to guide the selection of control technologies based on specific waste stream chemical characteristics.

- Familiarity with the details of how chemicals are used in the process under consideration, including an understanding of the nature and amounts of waste streams requiring control technology application.

- Knowledge of environmental statutes, and regulatory requirements pertaining to environmental releases (e.g., water and air emissions), waste disposal requirements (e.g., landfilling), and the applicable control technologies.

Within a business or DfE project team, the people who might supply these skills include a plant engineer, environmental engineer, line supervisor, regulatory specialist, or suppliers of control technology equipment.

DEFINITION OF TERMS: The following definitions are compiled from EPA regulatory documents and the references listed in Table 9-3.

<u>Absorption:</u> A unit operation involving the removal of a substance from a gas by contacting the substance with a liquid into which the desired component dissolves. The rate of transfer of the desired material from the gas to the liquid is dependent on its concentration in the gas and the liquid, the mass transfer coefficients in each phase, the solubility of the material in the liquid, and the amount of gas-liquid interfacial area available. Typical examples of importance in pollution abatement are the removal of sulfur dioxide from stack gases by absorption with alkaline

solutions and the absorption of carbon dioxide from combustion products into aqueous amine solutions.

Best Available Control Technology (BACT): A term applied to control technologies required under the Clean Air Act and its amendments for certain air releases from major new sources depending upon the class of attainment area. EPA determines BACT requirements by: (1) identifying all control technologies; (2) eliminating technically infeasible options; (3) ranking remaining control options by effectiveness; (4) evaluating the most effective controls and documenting results; and (5) selecting BACT.

Best Available Control Technology Economically Practical (BAT): A term applied to technology-based effluent limitations required under the Clean Water Act for certain water releases from existing sources. More recently-issued permits are likely to require compliance with BAT standards, which are usually more stringent than BPT standards.

Best Conventional Pollution Control Technology (BCT): A term applied to technology-based effluent limitations required under the Clean Water Act for water releases of conventional pollutants (e.g., oil and grease, fecal coliform, biochemical oxygen demand, total suspended solids, pH) from certain existing sources.

Best Practicable Control Technology Currently Available (BPT): A term applied to technology-based effluent limitations required under the Clean Water Act for certain water releases from existing sources.

Carbon Adsorption: Adsorption is the accumulation of a substance at the interface between two phases. In carbon adsorption, gases, liquids or solutes sorb onto the surface of activated carbon. Carbon adsorption is most frequently used for VOC abatement.

Chemical Oxidation/Reduction Reactions: Those reactions in which electrons are transferred from one chemical species to another, resulting in the oxidation state of one reactant being raised, while the oxidation state of the other reactant is lowered. When electrons are removed from an ion, atom, or molecule, the substance is oxidized; when electrons are added to a substance, it is reduced.

Chemical Precipitation: A process by which a soluble substance is converted to an insoluble form either by a chemical reaction or by changes in the composition of the solvent to diminish the solubility of the substance in it. The precipitated solids can then be removed by settling and/or filtration.

Disposal: Defined by the Resource Conservation and Recovery Act (RCRA) as the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including groundwater.

Electrodialysis: Process to remove ions from water by forcing their migration through a membrane with an electric field.

Electrolytic Recovery: The use of ion-selective membranes and an electric field to separate anions and cations in solution, used primarily for the recovery of metals from process streams or waste waters.

Evaporation: The conversion of a liquid into vapor. In waste treatment, evaporation involves the vaporization of a liquid from a solution or a slurry. Evaporation is commonly used for the removal of water from sludges.

Filtration: A method for separating solid particles from a fluid of liquid or gas, through the use of a porous medium, that retains the particles as a separate phase or cake and allows the filtrate to pass through. The driving force in filtration is a pressure gradient, caused by gravity, centrifugal force, vacuum, or higher than atmospheric pressure.

Fluidized Bed Incineration: Process using a single refractory-lined combustion vessel and high-velocity air to either fluidize the bed (bubbling bed) or entrain the bed (circulation bed); primarily used for processing sludges or shredded solid materials.

Hazardous Air Pollutants (HAPs): A statutory list of designated chemicals deemed hazardous as defined by the Clean Air Act and its amendments.

Hyperfiltration: A method to separate ionic or organic components from water by limiting the size of membrane pores through which a contaminant can pass.

Incineration: The destruction of wastes by high temperature oxidation (e.g., burning). Liquid injection incineration is used for gases, liquids, and slurries, while rotary kilns are used for all types of wastes including solids.

Ion Exchange: A process where undesirable ions are removed from an aqueous waste stream via exchange with counterions associated with an interactive polymer resin matrix, well-suited to the detoxification of large flows of waste water containing relatively low levels of heavy-metal contaminants, such as those emanating from electroplating facilities.

Liquid Injection Incineration: A process where a pumpable liquid waste is burned directly in a burner (combustor) or injected into the flame zone or combustion zone of the incinerator chamber (furnace) via nozzles.

Lowest Achievable Emission Rate (LAER) Technology: A term applied to control technologies required under the Clean Air Act and its amendments for air releases from certain new sources in nonattainment areas. LAER is the most stringent emission limitation derived from either of the following: (1) the most stringent emission limitation contained in the implementation plan of any state for such class or category of source; or (2) the most stringent emission limitation achieved in practice by such class or category of source.

Maximum Achievable Control Technology (MACT): A term applied to control technologies required under the Clean Air Act and its amendments to achieve acceptable emission limits for HAPs (see above listing).

Membrane Separation: A process which separates a contaminant (solute) from a liquid phase (solvent, typically water) by the application of a semi-permeable membrane and includes reverse osmosis, ultrafiltration, hyperfiltration, and electrodialysis.

Molten Glass: A process which destroys and/or immobilizes hazardous wastes into a stable glass form. The final product is reduced in volume and mass by driving moisture from the waste permanently, destroying portions of the waste thermally, and consolidating the residuals into a dense glass and crystalline product.

Ozonation: The treatment of industrial waste or waste water using ozone (O_3) as an oxidizing agent.

Pyrolysis: The chemical decomposition or change brought about by heating in the absence of oxygen.

Reasonably Available Control Technology (RACT): The lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. Applied to control technologies required under the Clean Air Act and its amendments for certain air releases from major existing sources in ozone non-attainment areas

Reverse Osmosis: A membrane-separation technique in which a semipermeable membrane allows water permeation while acting as a selective barrier to the passage of dissolved, colloidal, and particulate matter used to separate water from a feed stream containing inorganic ions.

Rotary Kiln: Equipment which provides a number of functions necessary for incineration. A rotary kiln provides for the conveyance and mixing of solids, provides a mechanism for heat exchange, serves as host vessel for chemical reactions, and provides a means of ducting the gases for further processing.

Sedimentation: The process by which particles are separated from a fluid of liquid or gas by gravitational forces acting on the particles. Sedimentation is often used in removal of solids from liquid sewage wastes.

Solidification: A treatment process in which materials are added to the waste to produce a solid. It may or may not involve a chemical bonding between the toxic contaminant and the additive.

Stabilization: A process (such as solidification or a chemical reaction to transform the toxic component to a new, nontoxic compound or substance) by which a waste is converted to a more chemically stable form.

<u>Stripping</u>: A physical unit operation in which dissolved molecules are transferred from a liquid into a flowing gas or vapor stream. The driving force for mass transfer is provided by the concentration gradient between the liquid and gas phases, with solute molecules moving from the liquid to the gas until equilibrium is reached. In *air stripping* processes, the moving gas is air, usually at ambient temperature and pressure, and the governing equilibrium relationship is Henry's Law Constant. In *steam stripping* processes, the moving gas is live steam, and the vapor-liquid equilibrium between water and the organic compound(s) is the key equilibrium relationship. Steam stripping is more widely applicable than air stripping because it can effectively remove less volatile or more soluble compounds.

<u>Treatment</u>: Defined by RCRA as any method, technique or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize it, or render it nonhazardous or less hazardous or to recover it, make it safer to transport, store, or dispose of, or amenable for recovery, storage, or volume reduction.

<u>Ultrafiltration</u>: The application of membranes to separate moderately high molecular weight solutes from aqueous solutions, primarily used to separate organic components from water according to the size (molecular weight) of the organic molecules.

APPROACH/METHODOLOGY: The following presents a summary of the technical approach or methodology for identifying potentially applicable control technologies for treating or controlling a waste stream. Methodology details for Steps 7 and 8 follow this section.

Step 1: Obtain a description of the unit operations and the process flow diagram for the baseline and substitutes from the Chemistry of Use & Process Description module.

Step 2: Review the Workplace Practices & Source Release Assessment module to identify the sources, nature and quantity of releases from the baseline and alternatives.

Step 3: Review the Regulatory Status module to identify any control technology requirements for the baseline and the substitutes. For example, air releases may be subject to the required use of MACT or BACT. Water releases may be subject to BAT or BPT control technology requirements.

Step 4: Use the results of Steps 1 through 3 to identify the waste streams, if any, that will be the subject of the control technologies assessment. If a regulatory requirement exists for certain waste streams generated by the baseline or the alternatives, it must be included as part of the process in the CTSA, with some exceptions. For example, if the CTSA is focussing on small businesses that are exempt from regulatory requirements due to the quantity of wastes or emissions they generate, it may not be necessary to include control technologies required for major sources.

Step 5: Obtain physical/chemical properties of the chemicals of concern in the waste streams identified in Step 4 from the Chemical Properties module.

Step 6: Obtain chemical fate properties (e.g., biodegradation data, biochemical oxygen demand, chemical oxygen demand, etc.) and treatability summaries for the chemicals of concern from the Environmental Fate Summary module.

Step 7: Characterize the waste streams identified in Step 4 to determine the concentrations of hazardous constituents and properties needing modification (e.g., acid neutralization) for treatment/disposal.

Step 8: Prepare a list of potential treatment processes or control technologies that provide the desired function (e.g., acid neutralization, removal of cyanides, etc.) while meeting regulatory requirements.

Step 9: Provide a list of candidate control technologies to the Cost Analysis module so that the cost of the controls can be estimated. It may also be necessary to provide this information to the Energy Impacts and Resource Conservation modules, particularly if the potential control technologies are energy-intensive or require treatment chemicals and/or water. Also provide the type of control and its removal efficiency (e.g., the amount of pollutants that it typically removes from a similar waste stream) to the Exposure Assessment module.

METHODOLOGY DETAILS: This section provides methodology details for completing Steps 7 and 8. If necessary, additional details on this and other steps can be found in the published guidance.

Details: Step 7, Characterizing Waste Streams

Table 9-2 gives examples of waste characteristics and the objectives of treating the waste.

TABLE 9-2: WASTE CHARACTERISTICS AND TREATMENT OBJECTIVES

Waste Characteristic	Treatment Objective
Corrosive	pH neutralization.
Flammable	Destroy active component.
Reactive	Consume active component in a controlled reaction.
Toxic	Destroy toxic constituents.
Bio-hazardous	Destroy biological hazard.

Details: Step 8, Identifying Potential Treatment Technologies

Figure 9-2 illustrates the applicability of broad classes of treatment technologies to certain types of waste streams.

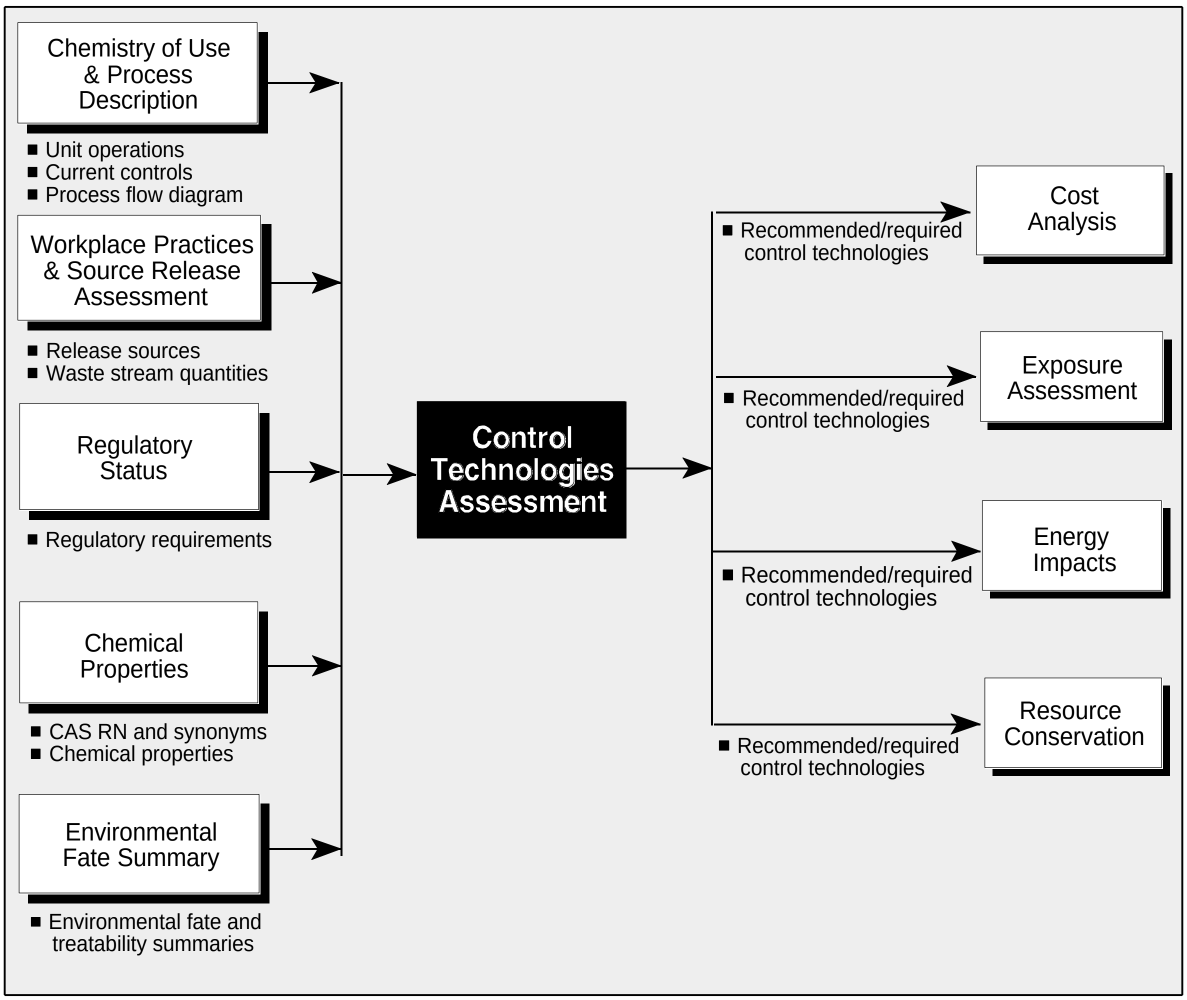
FIGURE 9-2: POTENTIAL TREATMENT TECHNOLOGIES BY TYPE OF WASTE STREAM

	Type of Waste Streams												Form of Waste		
Treatment Technology	Corrosives	Cyanides	Halogenated solvents	Nonhalogenated solvents	Chlorinated organics	Other organics	Oily wastes	PCBs	Aqueous with metals	Aqueous with organics	Reactives	Contaminated soils	Liquids	Solids/sludges	Gases
Separation/filtration		X	X	X	X	X			X	X			X		
Carbon adsorption									X	X	X		X		X
Air and stream stripping			X	X	X	X				X			X		
Electrolytic recovery									X				X		
Ion exchange	X								X	X			X		
Membranes									X	X			X		
Chemical precipitation	X												X		
Chemical oxidation/reduction		X								X			X		
Ozonation		X		X		X					X		X		X
Evaporation			X	X	X	X	X						X	X	
Solidification	X	X										X	X	X	
Liquid injection incineration			X	X	X	X	X						X		X
Rotary Kilns			X	X	X	X	X	X				X	X	X	X
Fluidized bed incineration			X	X	X	X	X	X				X	X	X	X
Pyrolysis			X	X	X	X						X	X	X	
Molten glass			X	X	X	X	X			X			X	X	X

Source: Freeman (1989).

FLOW OF INFORMATION: This module can be used alone to guide the selection of control technologies for treating or controlling waste streams in a facility. In a CTSA, this module receives data from the Chemistry of Use & Process Description, Workplace Practices & Source Release Assessment, Regulatory Status, Chemical Properties, and Environmental Fate Summary modules and transfers data to the Cost Analysis, Exposure Assessment, Energy Impacts, and Resource Conservation modules. Example information flows are shown in Figure 9-3.

FIGURE 9-3: CONTROL TECHNOLOGIES ASSESSMENT MODULE: EXAMPLE INFORMATION FLOWS



ANALYTICAL MODULES: Various computer programs are available for either monitoring, controlling, or managing air emissions, water discharges, and hazardous wastes. Check with EPA Headquarters (Washington, D.C., 202-382-2080) or consult trade magazines for information on the software packages currently available.

PUBLISHED GUIDANCE: Table 9-3 presents references for published guidance on the selection of control technologies to mitigate waste releases.

TABLE 9-3: PUBLISHED GUIDANCE ON CONTROL TECHNOLOGIES ASSESSMENT

Reference	Type of Guidance
Freeman, Harry M. 1989. *Standard Handbook of Hazardous Waste Treatment and Disposal*.	Information on various treatment technologies for hazardous waste.
Masters, Gilbert M. 1991. *Introduction to Environmental Engineering and Science.*	Provides overview of treatment technologies for hazardous waste.
Reynolds, Tom D. 1996. *Unit Operations and Processes in Environmental Engineering.*	Information on the design of processes to treat industrial waste.
U.S. Environmental Protection Agency. 1987c. *A Compendium of Technologies Used in the Treatment of Hazardous Wastes.*	Describes the various treatment technologies available for air, water, and land releases.
U.S. Environmental Protection Agency. 1990b. *Treatment Technologies.*	General information on treatment technologies for waste streams.
Walk, Kenneth and Cecil F. Warner. 1981. *Air Pollution, Its Origin and Control.*	Information on the regulatory aspects of air pollution and treatment methods to mitigate its impact.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

DATA SOURCES: None cited.